Remembering and Forgetting:
Exploring the Role of the Record in the Conduct of Scientific Research

Kalpana Shankar

Abstract

Although the creation of primary documents and records is fundamental to the conduct of contemporary science, there has been little research into the nature of these documents and the role they play in the daily conduct of research. In this paper I report on an ethnographic study in which I examined the role of records and record keeping in the lives of individual scientists. I explore how these researchers use documentary creation to make concrete the processes of learning, skill building, and becoming part of a larger system of discipline and profession. I show that documents do more than affix personal time and scientific memory; they also help craft the history and space of the laboratory itself. I conclude by reflecting on how technologies of various kinds become part of the processes of information creation.

Scholars have paid a great deal of attention to writing in science, particularly the act of formal writing and publication as they contribute to knowledge production and dissemination. But publication is only one site of intersection between science and the production of texts. Other kinds of writing, particularly records of daily activity and research, constitute the bulk of scientific documents and form an essential informational infrastructure in research science. When it is successful, a good infrastructure blends into the background, invisibly and silently underpinning the conduct of other tasks (Star & Ruhleder, 1996). When infrastructure breaks down or is deliberately laid bare, the observer becomes aware that infrastructure does not arise (or become embedded in social practice) by accident. Instead, institutions and individuals make choices that preserve the continuity and integrity of the system of choice. While there has been a recent surge among scholars to look at record keeping as informational infrastructure (Botticelli, 2000), very few have studied the role of daily laboratory record keeping as a successful and deliberate scientific infrastructure.

Scientific records, indeed all records, are not just a static form of organizational memory. Instead, for those who know how to "read" them, they create memory, while documenting other kinds of passages, marking the historical developments of individual and laboratory and even the discipline of research. In short, the acts of documenting scientific practice serve to document and coconstitute in highly idiosyncratic ways the trajectories of individual experience, the local history of the laboratory,[1] and the physical and social space that is the laboratory. In this paper I will discuss some themes regarding the role of records in the conduct of science. I recently conducted an eight-month ethnographic study that examined the record-keeping practices of a group of academic experimental physiologists. In addition to my field notes I relied on interview materials and samples of primary laboratory documents (electronic and paper).

Learning, Forgetting, and Documenting: The Record of the Individual Scientist

Someone new to the research experience or to a particular laboratory environment is engaged in many kinds of

[1] Scientists tend to use laboratory to mean two things: both the physical space where experiments are conducted and the social space associated with a researcher, his or her staff, and the students and research program. I tend to use the word in both contexts but will differentiate when appropriate.

learning that continue through the doctoral and postdoctoral stages and beyond. The simplified and stylized record keeping in classwork and routine laboratory projects aside, the development of a personal style of record keeping is constantly being relearned through trial and error, so much so that entwined in the process of being a professional scientist is the process of being a "good" (or effective) record keeper. The tension between developing a personally useful system and one that adheres to the standards of the profession is constantly being negotiated.

Veronica, a new graduate student, began a rotation in Philip's lab during the period I was observing the laboratory. Michael, a postdoc, worked with her to help her find a small project she could complete in a short amount of time and to teach her some techniques she would need for the kind of projects she wanted to do. One afternoon when Michael was on vacation, Veronica came into the lab and decided she would practice dissecting a frog. She asked if I would like to watch, and as I had yet to watch a frog dissection in the laboratory, I said I would and thanked her. We moved into one of the smaller laboratories off the main room, where dissections were generally done. Veronica carefully weighed her frog and measured its external organs, noting its dimensions in her notebook. She set her frog under the microscope and, using a scalpel, cut a midline down the frog's center. She peeled back the skin from its head and hesitated. She consulted her loose-leaf notebook several times during this procedure and then shook her head and said apologetically, "I took notes when I was watching Michael do this dissection, but my notes aren't very good." While she was saying this to me, Mary, an undergraduate who had been working in the laboratory longer than Veronica, came into the room. Veronica asked her, "Do you know how to do this dissection?" Mary asked, "What are you looking for?" Veronica replied, "The stapes and middle ear. My notes aren't good enough. I think there was a book . . ." They left for Philip's office and his collection of reference books, and I left them alone to puzzle through the dissection.

Veronica's experience at this stage in her graduate career suggests that learning to do research includes the development of efficient mechanics of record keeping. As a new graduate student her techniques of record keeping were as inchoate as her laboratory techniques, a fact that caused her difficulty in duplicating the techniques she had observed and now needed to recreate on her own. However, in the research environment it would seem that the development and stabilization of the former are intrinsic to the development of the latter. While the act of documenting one's learning processes might not be classed as part of the organizational record in most other contexts, it is an intrinsic part of the scientific record because it is so entwined with the daily practices of research. Although E. Yakel (1996) suggests that organizations need "artificial memories" far more than individuals do, records are more than artificial memories: they are also arguments. Individuals create scientific records to argue (at first to oneself and then perhaps to others) the rightness and completeness of their thoughts and actions. The nature of the daily scientific record suggests that capturing technical knowledge (the amount of a reagent that was added, the species of organism used and its characteristics) is as necessary for creating a reliable record as the delineation of the physical processes of research (for example, the order in which the scientist conducted the various steps of the experiment, the time at which the procedures were conducted, and the observations made with eye and ear), because the latter cannot exist without the former.

Veronica's experience also illustrates that records document more than one kind of learning and doing. Of course, becoming a professional in any field requires multiple kinds of learning—the content of the field, the techniques required to make new contributions to the discipline, and the invisible ecology of knowledge and practice. This repertoire includes in many cases the keeping of particular kinds of records and documents. The professionally and socially acceptable ways in which records must be kept are part of the repertoire of many professional practices. These practices have to be learned because records are often used as evidence of action taken and to shape the opinions of those outside the organization (van Maanen & Penland, 1994). Accounting for one's acts is a fundamental consideration in environments where institutional demands instill certain expectations (Meehan, 1986). Even scientists in a laboratory in which data are generally not shared are aware that the ethos of their profession demands that their records be intelligible to other people; some basic rules of form and organization of those records need to be followed if they are to be used as evidence of results achieved, for accountability, and to enable the replication of experimental procedures and practices. In short, the scientific record captures not only the development of an individual's path of learning on the way to becoming a scientist but also the very ways in which the record is created as part of that technical achievement and growth. Learning to document one's work in ways that are useful to oneself,

that are acceptable to the scientific community, and that reflect one's learning and growth help to create one's personal information infrastructure.

The need to document one's work effectively so that all these needs are met is not limited to official "students"—the undergraduates and graduate students. With each new project and each new laboratory one's personal techniques for creating standardized documents, labeling one's data, and creating a coherent, reliable record undergo evaluation and tweaking. With these processes of learning come increased confidence in the documents one creates and uses in one's research, even though the scientist may not articulate the creation of technical documents as an essential part of his or her professionalization process. Michael describes how his record-keeping techniques changed during the course of his research project:

> At the beginning, with the first five or six frogs, I wasn't taking accurate measurements. I was just doing basic dissections. So when I started taking proper measurements, I actually ordered the grid lens, which is key to the measurements. That's when I started numbering the frogs, and I went back and numbered the previous frogs as well because I'm an anal kind of person who likes keeping meticulous notes when possible—even in retrospect [laughs]. I suppose I shouldn't. After a few weeks of doing this [keeping meticulous notes], I realized that although I knew in my head what the results were, I didn't actually have any data printed out. I didn't have the data files organized in any way; so (in retrospect again) I went over my recorded data files. I did pretty much the same thing every day, or something slightly different, and I would always call it "crap" or "calibration1" or something like that. I called it the same thing every day. And suddenly I realized I had a whole folder full of stuff called "crap" and "calibration1." I didn't know what day I had recorded it. It was only a list of numbers. I didn't know what the conditions were or where I recorded the data. I realized that I had to come up with a better numbering system. From then on I've numbered all my experiments by date.

This incident suggests that Michael's efforts to stabilize his record keeping and his subsequent imposition of an order on his personal information environment became as integral to his development as a postdoctoral researcher as was his learning the new techniques of experimental physiology. Here Michael's system for organizing his records indicates an alignment of external, artificial memory (as represented by his laboratory notebooks) with the realities of his newfound expertise in his field. Part of the trajectory of personal experience in most learning situations is developing confidence in one's abilities, knowledge, and expertise. In Michael's words:

> In theory . . . when I was first starting off, I didn't keep such detailed notes, but I learned from my mistakes and found that I needed to keep notes. I would look back at previous experiments and not be able to figure out what I was actually doing [laughs]. It's important to have a good experiment numbering system so you can work out which experiment you were doing and exactly what you were doing on that experiment on a particular day. So after a couple of months of mucking around, it settled out, and I've been recording everything since.

Although both the daily practice and the scientific method demand the maintenance of complete and detailed records (for results to be replicable), Michael's experiences suggest that the scientist may need to impose some kind of management or indexing system after the fact to make a record "good." That "good" is highly subjective and relative. Michael's somewhat sheepish admission that he had created a numbering system for his experiments only after he had done them and that he had indexed his experiments subsequent to doing them indicates that he is aware his practices are not necessarily "canonical" or "textbook" (Macrina, 1995) but are clearly necessary. Susan, another postdoctoral fellow in the laboratory, expressed similar opinions when she explained her own system of record keeping to me:

> So these are sort of like cheat sheets. I use them mostly a) so that I have a record of exactly what I did and b) because I have a horrible memory. This is sort of like my adjusting to the fact that I have a horrible memory.

Veronica's anxieties early in her graduate student career and the "re-learning" that Susan and Michael went through as they made the transition from graduate school to their new postdoctoral fellowships exemplify two important points. First, they suggest some ways in which the act of documentation is a learned practice, constantly refined through use and reuse. Second, they suggest that documentation and record keeping are craft, not science. Although Susan and Veronica were given some "training" through rudimentary biomedical ethics courses and laboratory-oriented classes, the artificiality of such environments and the relative lack of importance placed on record keeping are not necessarily

conducive to learning how to create and manage personal sources of information and records. Concomitantly, the creation of a personal system that overcomes these difficulties is a cause for satisfaction and a sense of professional achievement.

The skills that one brings to bear to create useful, reliable records are part of the craft knowledge of scientific practice, skills that are part of what S. Delamont and P. Atkinson call "textual enculturation, where certainty and facticity of the natural world are reaffirmed" (2001, p. 103). Even though learning to record is such an intrinsic part of becoming a scientist, its nature as craft knowledge is omitted from the final work of science, the publication, in the same way that other kinds of tacit knowledge are both consciously and unconsciously laundered out. The rhetorical strategies and techniques used to shape the publication and the processes used to launder out the idiosyncrasy of the record-keeping process work together to reflect "certainty and facticity" as they are learned as a part of membership in a scientific discipline.

Michael, who also noted that he documented new techniques and procedures, suggested to me that learning new techniques, documenting how they work for him on a day-to-day basis, and the development of technical expertise over time are inextricably bound to an individual's experiences because recording the development of expertise is a subjective process.

> A lot of comparative anatomy depends on what you've seen before. Someone who came to a particular ossicular structure, let's say for the first time, . . . would most likely concentrate on features. They'd say "look at that long finger, look at that bony process." A more experienced anatomist might ignore such features because they're present in all the animals and they're not very interesting. What is much more interesting is a very small feature that someone else wouldn't notice. A lot of it is experience. You have to choose what you're going to talk about, and from that point of view it is entirely subjective.

Knowing how to look for the "interesting feature" and developing the skills to notice it require careful, conscious attention to developing one's skills—both as a technician and as a documenter of that technical skill. Eventually, with sufficient time and repetition these kinds of technical expertise become tacit knowledge—knowledge in the body that does not require articulation to be actualized. The record becomes embodied because it is directly produced by the body's intervention in the material reality of what is studied and what is recorded about the objects of study. The capture of experience and technique makes it even more so, because eventually the knowledge of craft or artisanry is that which is learned by the body and memorized by the hands.

Learning the techniques, developing confidence in one's knowledge and skills, and acquiring membership in the scientific profession are built on the documents underpinning the work of science. Documents are traces of the process of simultaneously learning with the body and forgetting with the brain, as in learning to drive a car or ride a bicycle. Peter Botticelli suggests: "Records can be said to act by limiting, or expanding, the contents of human social memory, either by forcing us to recall something, using text to jog our memory, or helping us to forget something" (2000, p. 174). It seems obvious that records allow scientists to learn and remember, but Susan's and Michael's comments suggest that records also allow them to forget—because writing down what they have done and how they have done it frees the mind from having to retain that information. The scientist thus learns a technique three times: first, when the skill is performed by the hands and learned by the body; second, when those motions are recalled subsequent times by being written up in the record; and third, when the technique must be summarized for publication or presentation. Each of these processes, through the accumulation of documents, becomes a highly personal entry point into the world of knowledge, craft, and socialization that becoming a scientist requires.

Time and Space: The Record and the Laboratory

But in spite of a great degree of latitude afforded academic researchers in the development of their individual style, individual scientists do not "do science" in a vacuum: each scientist is part of many larger systems. The documents and data collected by a scientist do not belong to that individual, nor even to the laboratory in which the individual works, but to the institution within which the laboratory is located. Nevertheless, the principal investigator in the laboratory acts as custodian of the records. If Philip chooses to pursue any particular project or assign a follow-up of an existing project to a new student or postdoctoral fellow, he expects to be able to use the records that were left behind by the person who had previously worked on that project. The records created by individual scientists must be such that the

scientist is confident that the records not only accurately reflect his or her own work but also are useful to the larger organization (here, that is the laboratory and possibly the research community)—a concept that is traditionally referred to as accountability by the archival community. However, as Yakel (2001) has noted in her study of the record-keeping practices of radiologists, accountability is not static. Nor is it so binary in nature. Instead, it is a process, a trajectory in and of itself. Developing accountability is part of the development of professional identity and experience. In the environment I have been describing, undergraduates, graduate students, and postdoctoral fellows come together to work and learn in a space and environment called "the laboratory." The interactions of individuals and their environment are documented and represented in multiple ways: the instruments they create, use, and borrow; the publications that result from their work; and, of course, the documentary record they leave behind.

Philip's laboratory is a popular one for undergraduate projects. He teaches courses in fieldwork and takes students on trips that last several weeks to Thailand and other countries to study frogs in the wild. His own research is conducted almost exclusively in the field and not in the laboratory, but there is leeway for the students with whom he works to pursue projects related to either or both.

The work that Philip and his colleagues and students are engaged in is dispersed both geographically and over many disciplines. Conducting research in animal communications requires that students and postdocs, especially those in Philip's laboratory, acquire new skills and update their knowledge on a regular basis. Philip explains:

> To go into the study of animal communication, you have to have an interest, if not a full technical background, in several areas. . . . There are at least five areas you have to be proficient in, and of course if you aren't when you arrive, you will be when you leave. You get trained in auditory neurophysiology, acoustics, computers, and statistics, and if you want to do fieldwork, you need fieldwork techniques.

Philip's laboratory rooms are fairly self-contained: they occupy several rooms and offices on one end of one floor. What constitutes the laboratory as a sociotechnical space, however, is dispersed across several continents, on multiple floors in the building (the animal rooms that Philip's lab uses are on another floor and the administrative offices that help administer his grants are in several buildings), in multiple disciplinary contexts, and most of all in the people that constitute the laboratory. What and where the lab *is* is dynamic and fluid, as the equipment, research projects, and researchers of the laboratory come and go. The lives of the people that constitute the laboratory are themselves in transition. As people complete coursework and term projects for their undergraduate degrees, conduct more sophisticated projects for graduate degrees and move on to other careers, visit the laboratory to collaborate on short-term projects, and complete postdoctoral research projects, they bring with them their personal and professional agendas and styles and leave an imprint on the laboratory through artifacts and documents.

P. Atkinson and A. Coffey write that "the collective organization of work is dependent on the collective memory that written and electronic records contain" (1997, p. 46). Objects and events in the laboratory are contextualized (or decontextualized), transformed, remembered, and forgotten by the people in the laboratory. The records and documents that people create are essential for constituting the space that is "lab"—by limning its periphery, creating its history, and reifying the web of relationships in which it participates. People can speak of artifacts in general and documents in particular as capturing the history of the laboratory because, while people come and go, the artifacts generally stay. This is especially true for the records, which are mandated by the rules of the funding agency to stay within the physical space of the laboratory. As a result the act of documentation and the ways in which documents are used uniquely and specifically construct the physical and social space and time that constitute that particular laboratory.

When I asked Philip to describe the tools he uses in the field, he showed me his "Write in the Rain" notebooks. These are small, yellow, hardbound notebooks that are waterproof and can be written in with pencil. Philip's collection of field notes spans twenty years of his career, from his doctoral work to his most recent trips. On the cover of each notebook Philip writes the geographical location of that field trip and the span of dates he was there. More recently he has begun carrying a laptop computer with him. Although Philip uses the computer to begin writing up what he will submit as a finished publication, he integrates his field notes

seamlessly into the process. When I asked him how he works with the notebooks, his computer, and the data within them, he said:

> In the field I use the computer to record the experiments. I haven't made notes so far in the field because we typically work at night [when the animals are active]. We get back *really* late, so we go to sleep right away. But the next morning I wake up and write notes—not necessarily as a notebook, but I start writing the manuscript so everything is fresh. I do the methods section, I record what instruments I'm using, what temperatures are being measured, locations, . . . and all that stuff. And I put it right into the computer. So that's my form of notebook in a way.

The process of scientific publication is usually idealized as a trajectory in which the various parts of the process are performed in particular locales: the scientist generates data and observations in the laboratory or in the field and then writes a formal conference poster or publication in the office to share that data with others at a conference in yet another location. However, information technology and the ways in which it is used to create and manage records confound that clear sense of place. Philip's use of his computer and his field notebooks to begin the formal publication in the field, even while he is gathering and recording data and teaching students fieldwork techniques,[2] blur office, laboratory, field, and classroom. These places become linked by the experiences of individuals and the records that are produced as a course of their daily actions. Philip's field notes (usually created in what Philip would call the "field," or in the physical space of the laboratory) and preliminary publication write-up (which would be written in a physical "office" space) unite the locally specific conditions of the field, the physical laboratory, and the office. As a result Philip's roles as teacher, writer, and researcher are also amalgamated through the blurring of physical and intellectual spaces (Bond, 1990).

The physical laboratory becomes a "backstage" of scientific inquiry, where mistakes can be made again and again until they are corrected and then published on the "front stage" of the refereed journal or poster. However, when the conditions in the physical laboratory are moved to the field, the field must be altered and brought home in some manner (Latour, 1983)—if not through such physical artifacts as frogs or other samples, then through the records that document the manipulation of those artifacts. Peter's students, his laptop computer, and the documents that Philip creates with field notebook and personal computer make concrete the translations Philip makes that allow his field site in Thailand to function as his classroom, his office, and his laboratory.

The laboratory is made simultaneously larger and smaller by information technology, and while Philip may welcome the convenience this affords him and the ways that it facilitated his work, others may not. The ambivalence of such sentiments echo the ambivalence many people feel about the portability of so many information technologies that can make a workplace of home and a home of the workplace. However, because records are intended for internal use and need to be kept for both the immediate and indefinite future, they help to shape the space that is the laboratory in ways that publications do not, because the scientific rhetoric of the formal publication deliberately obscures the situatedness of scientific practice and agency. As B. Latour (1983) has noted, publications minimize the particular conditions of the laboratory[3] where results are generated in a way that primary documents cannot. The confounding of place conferred by the portability of record-keeping technologies is not always welcome to every scientist. I described to Michael the advent and use of electronic laboratory notebooks in many areas of biomedical science, to which he replied: "Paper is more convenient. Who wants to sit in front of the computer all day long?" He added that he would not necessarily want to be able to access his working computer from home—"work is work, and home is home."

If the "space" that is the laboratory is expanded, contracted, and renegotiated through record-keeping processes and techniques, records still intersect with space in much more immediate and less metaphysical ways. Even though the ability to move texts and documents

[2] Each year he takes groups of undergraduate students to his field sites, where they learn some of the techniques of fieldwork "on the ground."

[3] Latour defines a laboratory as something beyond a place housing books, papers, apparatus, scientists, etc. It encompasses material arrangements that are specific to a particular group of scientists and their research interests, a place where inscriptions are created. Ultimately, the arrangements of the laboratory must be "translated" to the real world if the scientific statements made in the laboratory are to be deemed valid outside of it.

around and create them wherever they are needed expands the idea of what one calls the laboratory, records and their familiars, even digital ones, occupy physical space, a commodity that always seems to be in short supply in university settings. Although most granting agencies only require laboratories to retain records three years past the end of a grant period, binders of lab notes from students and scholars past still line the walls. Philip noted that he recently had to throw away many data disks and files because he no longer had room for them, even though he had kept many boxes of tapes and disks "from the old days." He also noted that obsolete technology did not pose a problem for him as the data from those tapes and disks had been analyzed and published, the retention period had ended, and he no longer had the appropriate technology to read those files.

In short, the records present an intriguing tension with respect to their relationship to physical space. The physical space in which documents are stored and created changes as new people are introduced to the lab, new research projects are begun, others are completed, still others are discontinued, and the research trajectories of a laboratory group change. Furniture is moved around to create new spaces for new kinds of work, and new pieces of equipment are purchased, while obsolete ones are retired. These physical changes to the space may need to be captured in the record because new equipment and new configurations of the physical layout of the laboratory can have an impact on the research itself through the introduction of new noises and vibrations or quirks in a new instrument. While the records that individuals create may capture that history, even the physical format of the documents that are created and maintained can indirectly serve as a marker of that history. The trajectory of research direction is reflected in changes in the "space" that is the laboratory, as the laboratory expands beyond the field site and the traditional wet lab to encompass information technology.

Conclusion

As scientists grow and become more confident in their technical and content expertise, the ways in which they keep and manage the record evolve. The resulting narratives of learning a technique and ultimately transcending it are captured both in the record and by the record, and the broader information systems in which the record participates. The ability to create reliable records anywhere in the world, share them with anyone, and blur the line between primary document and publication suggests that the laboratory as a scientific space grows and contracts as well. The record is a vast interconnected web of documents, data files, and drawings held together through the efforts of the record's creator and the principal investigator. Because of this highly personalized orientation the scientific record's place in organizational accountability is not as clear as it might be in more regulated organizations (Yakel, 1996), and "scientific accountability" seen through the record-keeping lens bears further exploration.

The lengthy process from recording observations in the lab and the interpretation of those records to the creation of formal publications should be studied more fully. The study of the complex process of record keeping, however, provides a point from which to begin asking questions about the publication process. I would argue that ethnographic studies such as this one contribute to our understanding of what constitutes current "best practice," while allowing us to speculate on how and why best practices arise. Frederic Holmes (1990), a historian of science, turned this around by asking how close studies of historical scientific records, such as those of Pasteur, might contribute to our understanding of the "routine" of science.

Although there has been a drive to develop systems to automate documentation processes through the development of Web-based "collaboratories" (Star & Ruhleder, 1996), electronic laboratory notebooks, and data audit mechanisms for validation (Loeb & Shamoo, 1989), such systems have had varying degrees of success, although they are in prevalent use in industrial settings. Often such systems are built on the underlying assumption that scientific record keeping (even in basic research) is uniform and implicitly understood by all researchers. Such systems (and when I use that word I include the work practices with which they are associated) are also not situated in a close understanding or acceptance of the microcultures of scientific research. Studying contemporary record keeping in context suggests that there is wide latitude in personal and local practice.

The study of records and the processes of scientific record keeping allow us to explore the tensions inherent in the development of individual processes of science vis-à-vis the standards of science as an institution. The record is an accretion of a functionally similar but stylistically idiosyncratic set of practices and documents, which in turn must be molded into a structured rhetoric of disinterested and formal publication designed to

communicate to one's colleagues. The processes through which this occurs can be seen as deeply embedded in the socialization of the scientist, the development of the social and physical space that is the laboratory, and ultimately the crafting of what constitutes "science."

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